MISB Motion Imagery Standards Board

MISB TRM 1003

Technical Reference Material

16 March 2010

Forward Error Correction for Motion Imagery over IP

1 Scope

Internet Protocol (IP) was never intended to carry real-time signals such as video. Advances in protocols like RTP are specifically designed for real-time signal delivery over IP; however, quality of service is still not guaranteed. IP data integrity is subject to the path taken where various disparate networks may be traversed and numerous router types encountered. Depending on network traffic data packets may be discarded because of congestion, reshuffled in arrival because of the different paths an IP packet may take, or delayed beyond their useful lifetime. Forward Error Correction (FEC) methods afford detection and correction of certain errors in data transmission, and so provide powerful tools in ensuring a certain level of data delivery. This document serves to illuminate the challenges in choosing a particular FEC method.

2 Normative References

[1] DVB Document A115, *DVB Application Layer FEC Evaluations*, May 2007

[2] Pro-MPEG Forum, Pro-MPEG Code of Practice #3 release 2, *Transmission of Professional MPEG-2 Transport Streams over IP Networks*, Jul 2004

[3] *The Impact of Packet Loss on an IPTV Network*, M. Luby, J. Miller, Digital Fountain, Jan 2007

[4] SMPTE 2022-1:2007, *Forward Error Correction for Real-Time Video/Audio Transport over IP Networks*

[5] SMPTE 2022-2:2007, *Unidirectional Transport of Constant Bit Rate MPEG-2 Transport Streams on IP Networks*

[6] ISO 13818-1:2007, *Information technology - Generic coding of moving pictures and associated audio information – Part 1: Systems*, 16 Oct 2007

3 Acronyms

AL-FEC	Application Layer FEC
CoP	Code of Practice
DVB	Digital Video Broadcasting Project
DVB-H	DVB Handheld (Mobile TV Format)
DVB-IPI	DVB Internet Protocol Infrastructure

FEC	Forward Error Correction
3GPP	3rd Generation Partnership Project
IP	Internet Protocol
QoS	Quality of Service
RTP	Real Time Protocol
TS	Transport Stream
UDP	User Datagram Protocol
WAN	Wide Area Network

4 Introduction

FEC is accomplished by adding redundancy to transmitted information using a FEC algorithm. Each redundant bit is a complex function of many original source data bits. The original data may or may not appear in the encoded output; codes that include the unmodified input in the output are **systematic**, while those that do not are **nonsystematic.** Forward Error Correction (FEC) is not always warranted because it can greatly inflate the bandwidth requirements of a communication channel, or conversely reduce the desired throughput for a given bandwidth.

The advantages of forward error correction are: 1) that a back-channel is not required, 2) retransmission of data can often be avoided (at the cost of higher bandwidth requirements, on average), and 3) lower latency than solutions that require a back-channel or retransmission. While the goal in FEC is to protect the signal from introduced errors caused by network conditions—one of which is congestion—adding FEC typically creates more data further exacerbating the congestion. Thus, there are certain applications where FEC can greatly improve data transfer and others where it may negatively impact overall network throughput.

FEC also requires processing time to both compute the correction codes at the transmitter and correct data at the receiver; it thus adds latency to the overall data transfer time. In a wide area network (WAN) this may not be an issue; however, in a tactical environment this may be unacceptable. Processing complexity is yet another criterion in choosing a FEC method; for example, mobile devices will be sensitive to intense calculations that degrade performance and battery life.

There are many FEC algorithms designed for specific applications that are better suited to correct certain types of errors. The application tends to drive the selection of a particular method. The challenges for an FEC system on an IP network is that, because of the UDP checksums, channel bit errors get translated into complete packet losses, and buffer and re-route issues cause burst packet losses. The combination of packet losses from the three sources – gross reordering, bit-error induced losses and burst losses needs to be low enough so that the FEC scheme is not broken more than the negotiated error rate.

No specific guidelines can be provided that will cover all application cases. Rather, the objective here is to make the community aware of industry choices and standardization efforts for FEC of data over IP networks. Also, the following ground rules should help guide the selection of a particular FEC method for use in our community: 1) the FEC method should be transparent; 2) the FEC method should not cause interoperability issues with current infrastructure; and, 3) ideally the method is an industry standard. Transparency means that decoders not designed to process the FEC can ignore the FEC and still recover the original signal; **thus only systematic FEC methods should be considered**. A special case outside this ground rule may be in dedicated point-to-point communications systems with a pre-established proprietary method that must be used. As long as any non-standard or proprietary FEC method is removed prior to further dissemination or storage, then this option should be allowed. Interoperability implies that the FEC does not cause issues with current infrastructure. That is, systems receiving a FEC-treated signal can still function without knowledge of the FEC data, or that sufficient information regarding the FEC method is provided for proper decoding.

5 Solutions for Data Loss

5.1 Physical/Link Layer Error Correction Codes

Although error correction schemes, such as convolutional and Reed-Solomon codes, are used at the physical layer on a single physical link such correction is intended to mitigate bit or byte errors and very short bursts. The Reed-Solomon scheme of 16 bytes of repair data for a 188-byte transport stream packet provides protection for only 8 bytes of loss—this amounts to 8.5% overhead. This also alters the size of a TS packet from 188 bytes to 204 bytes, thereby increasing the payload and bandwidth needed. Interleaving of data packets can improve the protection, but if the error rate exceeds the ability of these protection mechanisms, the packet is flagged as corrupt and considered unusable or lost. Increasing the amount of protection at the physical layer can reduce packet loss to some extent, but the added protection comes at the expense of extra bandwidth, thus either reducing the useable throughput of the channel, or requiring more channel headroom.

5.2 Application Layer Erasure Coding

Often called AL-FEC (Application Layer FEC), erasure coding attempts to restore lost packets missed by any physical layer error correction or lost for other reasons. Erasure coding has been adopted in such standards as DVB-H and 3GPP and the DVB-IPI specification for IPTV. Erasure coding differs from classical bit-level error correction in that the unit blocks tend to be much larger (whole packets vs. single bits) and the entire unit (or packet) is assumed lost or unrecoverable. Erasure correction can thus help eliminate packet loss, reduce the need to over-engineer the network, and reduce Quality of Service (QoS) overheads.

6 FEC Methods

FEC methods are classified as: error detection codes, error correction codes, and erasure correction codes each serving a different purpose. Error detection codes help determine whether the received data is in error, but do not provide the means to identify and correct the errors. Error correction codes help to identify and correct up to a certain number of errors occurring in the received data. Erasure correction codes help to correct up to a certain amount of missing data where the positions of the missing data within the total amount of data are already known.

In considering candidate FEC methods, two that have been adopted by industry have also been tested and evaluated [1] by the Digital Video Broadcasting Project (DVB):

- Pro-MPEG Code of Practice 3 (CoP#3) [2]
- Digital Fountain (DF) Raptor Codes [3]

CoP#3 has been adopted and standardized by the SMPTE [4, 5] and will likely find greater use in wire-line delivery. Raptor codes are proprietary erasure codes, and have been found valuable in wireless networks. Both are intended to correct errors in video over IP.

Designed specifically for MPEG-2 Transport Streams (TS) [6], CoP#3 uses RTP as the building block for providing packet recovery, and so requires that the transport stream packets be carried within RTP over UDP. RTP provides additional information such as a packet count and time stamp that can aid in determining when packets are missing and out of order. Data jitter can be accessed from the RTP time stamps. In the CoP#3 schema, MPEG-2 TS packets are carried in one RTP packet, while one-dimensional FEC correction data is carried in a second RTP packet (see Figure 1). Note that this second FEC RTP packet contains an additional FEC header to denote that these TS packets are the FEC protection data for the media packets. More protection can be added with yet a third RTP channel that carries two-dimensional recovery information. The advantage of this method is that one or more FEC channels can be ignored at the receiver (transparent), or elected to not be sent at all when there is insufficient bandwidth. The main channel, however, is exactly the same as that sent without FEC.

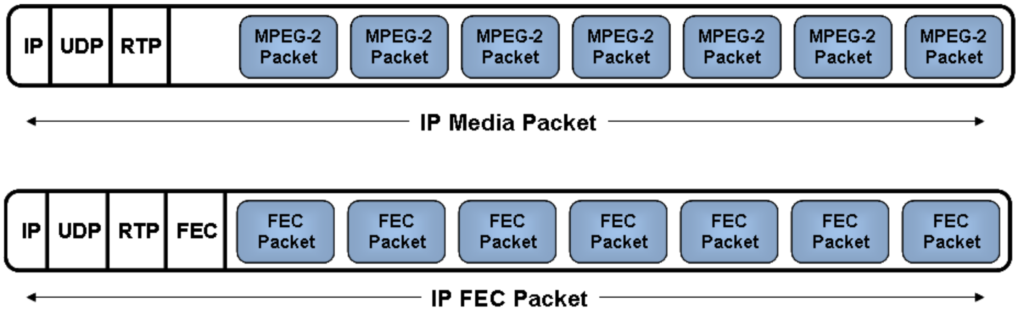

Figure 1: Media and FEC Data Carried as Separate RTP Streams

7 Summary

Neither technique discussed meets the two requirements of transparency and interoperability. CoP#3 is a standard. Raptor codes alter the original data so a receiver must have the capability to decode the stream; thus, this solution is not transparent and certainly not interoperable within the current infrastructure of our community. If RTP were adopted as the data carrier for MPEG-2 Transport Stream instead of UDP (i.e. TS/RTP/UDP/IP versus TS/UDP/IP) CoP#3—and now SMPTE 2022—could serve as an industry-standard method for FEC at the application layer.